Challenges and Opportunities for Use of Smart Materials in Designing Assistive Technology Products with, and for Older Adults

Danying Yang and Louise Moody

DOI 10.1080/17569370.2021.1938823
ISSN 1756-9370

Publisher: Taylor and Francis

Routledge
Taylor & Francis Group

Fashion Practice, 2021
DOI: 10.1080/17569370.2021.1938823

Challenges and Opportunities for Use of Smart Materials in Designing Assistive Technology Products with, and for Older Adults

Danying Yang and Louise Moody

Danying Yang is Researcher in Design. She engages in the design and research activities of the Centre for Arts, Memory and Communities at Coventry University. Her research interests lie in the area of Smart Fashion and Wearable Technology associated with innovative materials and textiles, with the focus on promoting the design and

Abstract

Despite the potential to support ageing in place, there is still low Assistive Technology (AT) uptake among older adults. Smart Materials (SMs) have the potential to play an important role in AT innovation without detracting from the aesthetic appearance and ease of use. The MATUROLIFE project aims to develop enhanced AT products for older adults by employing smart metallised textiles, through a design process

involving older adult users and collaborating within a complex interdisciplinary space. This paper outlines research undertaken to capture the prioritised needs and design requirements of older adults, as well as their expectations of future technologies and understanding of SMs. Following interviews with older adults exploring AT acceptance, 94 older adults were engaged in a series of co-creation workshops. The findings emphasise a strong need to feel independent yet safe in older adulthood, and an uncompromised requirement to be fashionable without stigma and stereotypes. The participants demonstrated no resistance to the adoption of smart materials and technologies if they are integrated into AT products that are easy to use, comfortable and aesthetically pleasing, irrespective of the complexity and novelty of the technology involved.

KEYWORDS: assistive technology, smart materials, technology acceptance, independence, co-creation

1. Introduction and Background

The ageing population is a global challenge (Partridge, Deelen, and Slagboom 2018) leading to an increased need for health and social care for older adults (NIHR 2018). With an increasing focus on "ageing in place", enabling older adults to remain as autonomous, active and independent within their own homes for as long as possible is a priority (Wiles et al. 2012; Iecovich 2014). Much research has considered the role technology can play in alleviating some of this demand (Frid et al. 2013; Pilotto, Boi, and Petermans 2018), with older adults themselves increasingly looking for new knowledge and tools that will enable them to remain independent and living well for longer. By helping to address the health, wellbeing and socio-economic issues, Assistive Technology (AT) can provide benefits at the individual level for older adults, as well as reducing caregiver burden and stress (Gaßner and Conrad 2010; Bloom et al. 2015; Marasinghe 2016; Pilotto, Boi, and Petermans 2018; NSTC 2019).

Despite the considerable potential and investment in AT, the actual use of AT provides a less positive picture. Globally, there are challenges due to the availability of limited and specialized assistive products, the lack of user-centred research and development, and context-appropriate product design (WHO 2018). There is a general lack of understanding of the individual need and behavioural choices as well as the wider context into which services are delivered (Demers et al. 2016; NIHR 2018). The "knowledge gap" between a design team (i.e. includes product designer, technologist and other subject experts) and the target users (i.e. older adults) can generate design problems in reality and hinder the development of assistive products (Hwang and Park 2018).

development of a variety of products through interdisciplinary collaborations and non-traditional approaches. danying.yang@coventry.ac.uk, yangdanying2007@yahoo.co.uk

Louise Moody is Professor of Health Design and Human Factors. She leads the Arts and Well-being strand within the Centre for Arts, Memory and Communities at Coventry University. Her interdisciplinary research is focused on the development and evaluation of technology and interventions for health and wellbeing. With a background in Psychology and Human Factors, she employs a range of research methods as well as art-based approaches to ensure that new products, systems, services and interventions are effective as well as being desirable and acceptable to end-users and stakeholders.

The three-year EU Horizon2020 (H2020-EU.2.1.3.) funded project MATUROLIFE (Metallisation of Textiles to make Urban living for Older people more Independent and Fashionable) seeks to tackle these issues in order to enhance AT acceptance among older adults and enable greater participation in society through the design of AT. The overall objective of the project is to embed smart metallised textiles in different AT products that support the independence of older adults whilst being easy to use and desirable to own. The project brings together 20 partners from nine EU countries (France, Italy, Spain, Belgium, Germany, Poland, Slovenia, Turkey and United Kingdom) and particularly focuses on the development of smart assistive clothing, footwear and furniture. These product areas present opportunities for use of textile-based Smart Materials (SMs) and in which partners have design and manufacturing capability. The project and proposed outcomes are complex, bringing together different disciplines to develop novel AT prototypes that embed SMs based on innovative selective metallisation techniques (Azar et al. 2020).

This paper presents research undertaken in the first nine months of the project to inform the design direction, technical development and scientific innovation within the project. The research sought to embed a user-centred approach and employ co-creation to ensure that the views and preferences of older adults inform the development of smart AT prototypes and the project direction. Here we describe research undertaken across the partner countries (through semi-structured interviews and co-creation) to explore older adults' day-to-day experiences, priorities and requirements in respect to their potential AT needs, openness to the use of SMs and practical pursuit in fashion.

1.1. Poor acceptance of AT by older adults

AT is identified as any device or system that is used to increase, maintain, or improve an individual's functioning and independence, and any service that is provided to assist in the selection, acquisition, and use of this sort of device or system (Individuals with Disabilities Education Act 1990). Examples of AT can be relatively low-tech and as simple as reading glasses, walkers, or grab rails. Alternatively, it can be more advanced using cutting-edge science and technology as digital devices, products and services for built-in communications and safety features or health monitoring capabilities (Davies et al. 2016; Boucher 2018; Holliday, Awang, and Ward 2018). Regardless of device complexity, AT can compensate for sensory, physical/mobility and cognitive impairments and seeks to maintain or improve functioning and independence to help people achieve a better quality of life (Lancioni and Singh 2014; Boucher 2018). Ongoing development of assistive devices, intelligent environments and services endeavours to enable older adults to live at home for longer and participate actively in society with increased autonomy and self-confidence (Gaßner and Conrad 2010; NIHR 2018).

A number of studies, however, have identified issues of acceptance and poor adoption of AT by older adults (Fisk et al. 2009; Lee and Coughlin 2015; Yusif, Soar, and Hafeez-Baig 2016). Instead of being "assistive", some products stigmatise the user by magnifying the individuals' physical and cognitive limitations (Spinelli, Micocci, and Ajovalasit 2016; Martins et al. 2016), and provide a source of frustration or lead to further isolation from society (Lee and Coughlin 2015; Yusif, Soar, and Hafeez-Baig 2016). These influences of societal stigma and social isolation can considerably affect AT adoption and use (Profita 2016). Advances of SMs in fashion provide the opportunity to explore new physical forms of AT products as being more interactive, comfortable and attractive, whilst it is also argued that there is limited focus on the needs of older adults in fashion (Twigg 2013; Yang and Moody 2020). By incorporating SMs and integrating aesthetic requirements in novel AT, the project aims to mitigate the stigma associated with monitoring and assistive devices for older adults.

1.2. Smart materials and technology to support older adults

Embodying the convergence of textiles and electronics (e-textiles or textile electronics), SMs are a new class of high-performance materials that can sense or react to environmental conditions or stimuli (e.g. mechanical, chemical, electrical, magnetic or other forms) (Tao 2001; Tang and Stylios 2006; Stoppa and Chiolerio 2014; Koncar 2019). In the last decade, SMs have had wide applications in sports, military, medicine and clothing allowing a shift from rigid and non-flexible electronic products (Stoppa and Chiolerio 2014; Gokarneshan and Srivatsav 2018). For example, sensor fabrication and assembly with SMs can be invisibly built into the garment as textile-based circuitry which can replace traditional wiring hence reduce discomfort and also be lightweight, washable and safe (Yang 2012).

There is increasing attention to the development of smart wearable healthcare devices with textile-based electronics and sensor fabrication (Gonçalves et al. 2018). This presents great potential for health monitoring and diagnostics as well as preventative and self-management approaches to health care (Jin, Jin, and Jian 2018). For example, monitoring daily activity patterns and frailty using smart wearable technologies can provide more accurate and up-to-date assessments of physical health and enable personalized, tailored care (Armstrong, Najafi, and Shahinpoor 2017). Wearable technologies incorporating SMs are expected to play a constructive role in addressing health-related issues. The use of SMs over the use of additional bulky and heavy electronic components should increase the potential functionality of AT alongside improving their appearance, and user acceptance and adoption. The SMs applied to three AT products in MATUROLIFE project employ selective metallization process to encapsulate metal-coated fibres in textiles to provide better integration of electronics and sensors into fabrics

and textiles. In this way, these SMs give the product and fashion designers the tools to produce AT for older adults that is not only functional but also appealing as being lighter and comfortable (Moody and Cobley 2020).

1.3. Design of AT and SMs with older adults

As Spinelli, Micocci, and Ajovalasit (2016) highlight, it is crucial to have a clear understanding of how the older adults perceive and respond to innovative approaches and the use of engineered materials in the design and development of AT to maximize the user experience and likely acceptance and use. Despite the availability of AT, there remains a substantial gap between what is designed and developed and what is wanted by the end-user, as a result the potential benefits of AT are not being fully realised (Peek et al. 2014; Lee and Coughlin 2015). Although SMs are looked upon as future of fashion, there is still limited research considering older adults' views on SMs or research involving them in designing and developing smart materials/functionalities (Micocci and Spinelli 2018; Micocci 2017). The development of SMs is to some extent experimental and technical. However, how the SMs are then integrated into the development of products warrants further consideration. The MATUROLIFE project is concerned with whether older adults can recognize and accept the potential benefits of smart materials and functionalities, as well as how engineers and material science specialist can develop highly technical solutions whilst embedding an understanding of user needs, wants, preference and requirements. This is being addressed using co-creation.

Co-creation is increasingly employed in redesigning healthcare services, technology-led programmes or interventions, and is effectively impacting the fashion system in which the users/customers are fully engaged in the overall innovation and improvement process (Bate and Robert 2006; Elg et al. 2012; Donetto et al. 2015; Townsend, Sadkowska, and Sissons 2017; Lee, Ahn, and Kim 2018). The co-creation activities bring people together to share knowledge and explore ideas from different backgrounds and disciplines, as well as involve users or customers working closely to develop solutions in helping to shape new products and services (Sanders and Stappers 2008; Ind and Coates 2013; Kim and Lee 2016). The use of collaborative approach aims to ensure that the design and technology of the products are grounded in the lived experience of the users/participants (Couvreur et al. 2013; Galvagno and Dalli 2014; Frow, McColl-Kennedy, and Payne 2016). Co-creation is employed in the MATUROLIFE project as a means to draw together views from a variety of stakeholder perspectives in the development of AT solutions that embed SMs.

1.4. Aims and objectives

The aim of this study was to determine and embed the views of older adults in the development of SMs based AT and ensure solutions are developed that meet user needs and requirements. Four key research objectives are addressed:

a. to identify the factors that encourage or affect the acceptance and use of assistive/smart technologies;
b. to prioritise the daily and future needs of older adults in the context of their daily life activities;
c. to identify how to employ smart materials/functionalities in AT concepts;
d. to identify design preferences and fashion/aesthetic requirements.

2. Methodology

Qualitative research methods are applied in the exploration and ideation stage of the project, considering sampling strategies and criteria to ensure sufficient information power for responsible data analyses (Ritchie et al. 2014; Malterud, Siersma, and Guassora 2016). Co-creation workshops were undertaken to bring together older adults and the MATUROLIFE multidisciplinary team to develop smart AT solutions. Semi-structured interviews were conducted before the workshops in order to inform the co-creation activities and workshop content. In total, 94 older adults aged between 60 and 95 years were recruited through our partner network across nine partner countries to ensure development was not focused just on the context of one specific country. The study was approved through the Coventry University Ethical Approval Process.

The research design outlined here sought to rapidly capture a broad sense of views, needs and priorities across partner countries at the start of the three-year project to inform the design and project direction, and establish user and stakeholder groups within each partner country. The wider project ambition was to develop prototypes that were applicable to needs across Europe. The participants and stakeholders involved in this research would then continue to inform iterative design cycles and prototype testing.

2.1. Identifying the critical factors affecting technology acceptability among older adults

In order to gain an understanding of older adults' attitudes and current experience in relation to assistive and smart technologies, semi-structured interviews were conducted with 37 older adults ($n = 26$ females and $n = 11$ males) across six of the partner countries (France, Italy, Poland, Spain, Turkey, and United Kingdom).

Table 1. Overview of the ten co-creation workshops.

Type of co-creation workshops	Country and city	Number of participants	Number of partners present	Objectives
Exploratory	Spain (Arnedo)	10	6	• To explore the needs of older adults. • To identify key threats to independence and broad requirements. • To discuss the main obstacles in adopting AT.
	Italy (Vittorio Veneto)	8	8	
	Belgium (Antwerpen)	14	5	
	UK (Coventry)	8	5	
Product focused - *Clothing*	France (Paris)	8	6	• To prioritise key threats to independence. • To review existing AT product features and style preferences. • To co-create ideas and early concepts for further development. • To understand SMs and smart functionalities.
	Slovenia (Domžale)	9	4	
Product focused - *Furniture*	Poland (Łuków)	10	5	
	Turkey (Istanbul)	8	5	
Product focused - *Footwear*	UK (Coventry)	9	5	
	Germany (Berlin)	10	5	

The interview schedule was designed to explore older adults' daily activities. Through a "journey/timeline mapping" approach (Bernard and Andritsos 2017; Cameron and Hunt 2018), the interviews provided "the big picture" of one day with older adults, and investigated the underlying factors affecting their technology acceptance including digital literacy, use of technologies promoting independence and well-being, views about AT, perception of SMs and attitudes towards clothing, footwear and furniture products.

The findings were used to provide a broad understanding of the context and personal experience of older adults to the project partners and to inform the design of the subsequent co-creation activities.

2.2. Co-designing assistive products with old adults to prioritise needs and identify preferences

Ten co-creation workshops were undertaken in nine European countries participating in the MATUROLIFE project (3 big cities and 6 smaller regional cities). Initially exploratory co-creation workshops were undertaken ($n = 4$, in 4 countries); followed by development workshops ($n = 6$, in 6 countries). The average length for each workshop was four hours, including the breaks. Ninety-four older adults ($n = 63$ female and $n = 31$ male) took part in the activities, working together with designers, manufacturers, human factors specialists, psychologists, and material experts. A summary of the workshops is shown in Table 1.

The workshops were scheduled to enable some confirmation/check of findings between countries as well as iteration of ideas in an iterative design process (Holliday, Magee, and Walker-Clarke 2015), as illustrated in Figure 1. The first set of exploratory workshops aimed to

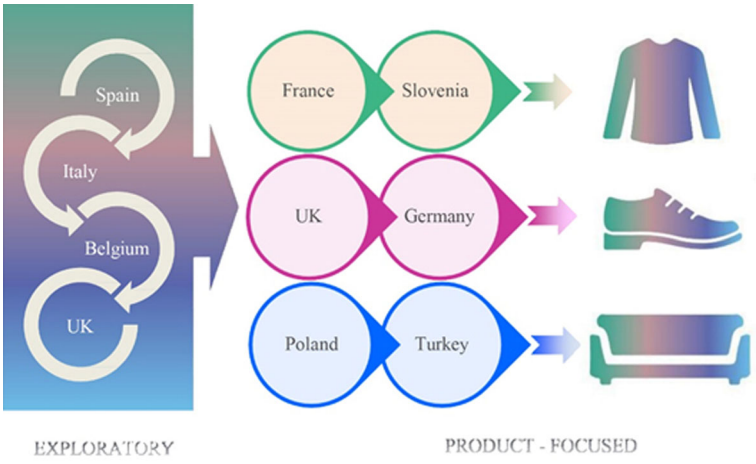


Figure 1.
Iterative design process involving two sets of co-creation workshops. Courtesy of Danying Yang.

inform and feed the development of the second set of product-focused workshops.

2.2.1. Exploratory co-creation workshops

The activities in the first set exploratory workshops in Spain, Italy, Belgium and United Kingdom aimed to scope the participants' views, concerns and challenges associated with their independent living, and build on the interview findings. The participants were asked to highlight possible health-related concerns or problems and were encouraged to generate ideas or solutions in response. There were also active discussions about acceptability of the existing AT products between designers, researchers and the participants. Through these activities, participants were physically engaged in brainstorming and recorded their thoughts and opinions using words, diagrams or sketches (an exemplar shown in Figure 2).

The exploratory workshops identified the priorities for older adults – the key threats to their independence and the areas in which they most wanted support, as well as design and functional preferences from the older adults. These findings further informed the subsequent product-focused co-creation workshops to consider addressing the priorities and preferences through specific product areas in footwear, clothing and furniture.

2.2.2. Product-focused co-creation workshops

The product-focused workshops then emphasized on the design and development of assistive clothing, footwear or furniture solutions. Two

Figure 2.
Conversation of the existing smart AT products and the concerns of independent living and well-being in the UK workshop. Courtesy of Danying Yang.

workshops were focused on each product area and conducted in different partner countries.

In the first activity, the participants were given eleven factors affecting independence on individual strips of paper and were asked to select the first five priorities that are considered relevant to them, and then shared their list with one peer. After working in pairs to agree on their top four, they reported back to the group and the results were combined as the top four priorities for the workshop.

Participants were then asked to sift through a collection of product images and indicate which they would purchase, use or wear for which activities, the features they liked/did not like and why. The images were tailored to the workshop with examples selected by project partners in different countries (i.e. shoes examples for the footwear workshops, an exemplar shown in Figure 3).

The participants (including project partners) then developed design ideas to address the key independence needs and embed their style preferences. Two teams were formed with older adults working alongside project partners including an engineer, human factors specialist, designers, and/or manufacturers (either footwear, clothing or furniture). The facilitators thereby encouraged consideration of the smart functionalities and explained how the application of embodied smart metallised textiles and sensor fabrication may enable the prioritised functionalities. The project partners contributed technology knowledge and ideas around

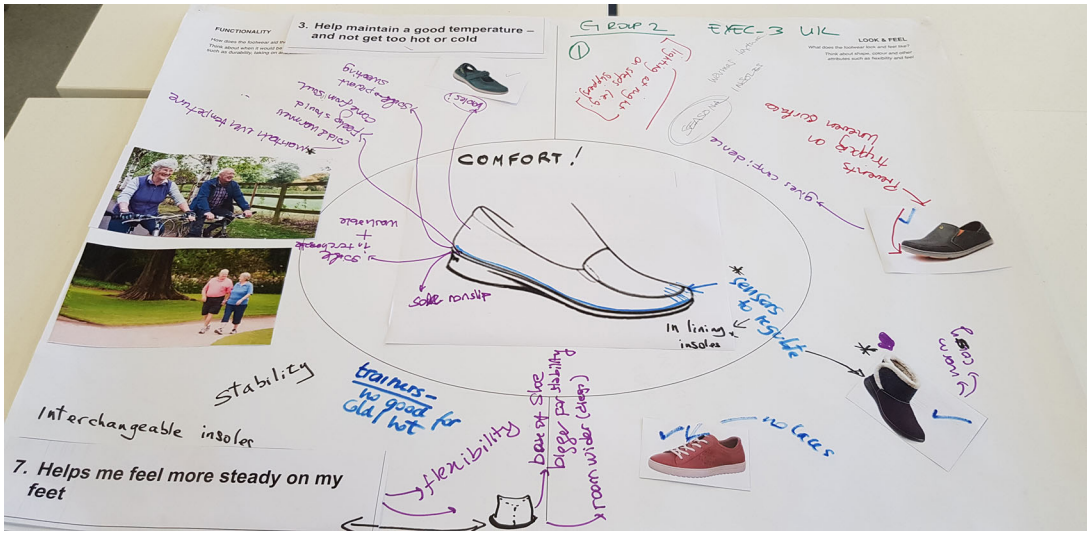


Figure 3.
Co-deciding the list of priorities/functionalities for the MATUROLIFE footwear concepts. Courtesy of Louise Moody.

specific construction techniques and materials. The older adults were encouraged to share their preferences and ideas about how information might be presented back to them from the smart solutions.

2.3. Analysing the qualitative data

All of the qualitative data from the interviews and workshops were audio recorded, photographic archived, transcribed, and thematic analysis undertaken. The data recorded and collected in different languages were translated into English. By using Computer Assisted Qualitative Data Analysis Software (CAQDAS), extensive rich materials were categorised and sorted by themes and sentiments in MAUROLIFE NVivo (v.11 Pro for Windows, ©QSR International) (Bazeley and Jackson 2013) project. Thematic Analysis (Boyatzis 1998; Nowell et al. 2017) and Affinity Diagramming (Martin and Hanington 2012) were used to scope out the factors affecting technology acceptance and the emergence of health-related priorities, whilst Qualitative Content Analysis (Schreier 2012) was used to sort the wish-list of design preferences for clothing, footwear and furniture.

3. Findings

3.1. Technology acceptance among older adults

The interviews and workshops provided a broad view of participant openness to technology usage. The findings suggested increasing usage and openness to the internet, computers and smartphones amongst older adults. Most of our participants commented that they use them to

communicate with family or friends, to obtain information, to read the news, and to keep their social engagements, whilst some participants did express doubts about new technology.

> We both have smart phones. I think those technologies overall improve our lives. I mean being able to communicate easily with my daughter in Dubai, and my son in Oslo or Hong Kong, so we can WhatsApp, Skype. So yes, that is all good. [UK, Interview Participant #3]

> I have smartphone but I do not use it because I do not know all functions. It is too complex. If I learn something but I do not use it, I quickly forget it. [PL, Interview Participant #2]

Participants also acknowledged the potential advantages of technology, in helping them to live independently and actively participate in society.

> To go ahead I think that all the technology for the health and medicine is important. We can detect and control the heartbeat of an astronaut going to the moon but on the other hand there is the woman living in the next door and falls on the floor, dies and nobody knows it. [IT, Workshop Participant #1]

One participant highlighted the importance of improving assistive devices and services for older adults.

> I cannot walk far with the stick, so I take my wheelchair to assist it… When I go to town by Ring and Ride, I got shop mobility scooter but you have to get the scooter back 16:15 the latest and they do not work on Sunday. Again, it is excellent service but it is limited. What I would like to say is – it is a struggle for older people. [UK, Workshop Participant #7]

Participants showed the openness to wearable devices and SMs that would provide assistance in the development of new ideas.

> I would wear without problem something that controls my health status, controlling my heartbeat and blood pressure for instance. [IT, Interview Participant #1]

> Sometimes, I think about inventing something, for instance, a jeans tracksuit to do sports in a more fashionable aspect. In my life, if some devices could preserve the memory, it will be fantastic. [ES, Interview Participant #8]

> It is important to consider materials and designs that absorb humidity and reduce sweating. I think it could be addressed through smart technological fabric. [FR, Workshop Participant #6]

They were more interested in getting instant feedback from smart material technology instead of using the platforms such as a smartphone or a computer to access information.

> Different sounds for different things. Light left on or cooker left on with different alerts for the actual thing. Different colours will work if you are deaf. [UK, Interview Participant #4]

> A product could change colour in order to inform someone about his/her vital signs. [ES, Workshop Participant #1]

To be accessible, participants emphasized the importance of smart technology being easy to use, empathetic and affordable.

> No, it will come but for now I don't understand it. I will change my phone. I am scared not to be able to use it. [FR, Workshop Participant #3]

> People said, well, you could use it by voice. I know I can but my voice changes and I got allergies in my voice. How does it work if your voice changes? To me it is wasting time. [UK, Interview Participant #7]

> Especially as it is expensive and we do not know it, we are afraid to turn it on and use it, so I prefer not to use it than to learn how to use it. [PL, Interview Participant #3]

Whilst there was an open mind and willingness to health monitoring conditions, there were also reservations about how "complicated" or "invasive" technology may become.

> These things exist already but they are not properly distributed. Some older people do not like to wear such products. I think the family somehow is not pushing properly the use of those products to them. [IT, Workshop Participant #1]

> I feel uncomfortable to be monitored by wired jacket, too intrusive. [UK, Interview Participant #5]

The workshop participants emphasised that not only should the technology be inconspicuous but also the design features must be attractive or aesthetically pleasing and suited to their age and preferences.

Table 2. The user needs and concerns raised during the four exploratory workshops.

High-level priorities	Health-related priorities
Good wellbeing as I age	• I sleep less well and have a poor sleep routine. • I easily get too hot, and / or too cold. • I easily get dehydrated (this can lead to falls and confusion). I need to drink more regularly. • I feel unsteady on my feet and fear falling. • My feet swell and I have poor circulation. • I need help to manage my medication.
Helping me feel safe when out and about	• It has got harder to find my way around. • My relatives fear that I may get lost or collapse.
Helping me feel safe at home alone	• It is getting harder to keep the house clean. • It would be good if people know when I need help, e.g. I have fallen; I have low pressure.

> This looks like a chair for a granny. It is similar to one I had in the house and my son wanted me to get rid of because it looked old. [UK, Workshop Participant #4]

> Anyway this looks athletic, not something that an older person would wear. It could be made to look less intrusive. [UK, Workshop Participant #8]

3.2. Health and independence related priorities

The study sought to prioritise the needs of older adults in the context of their daily life activities. Drawing from the interview and exploratory workshops, a list of the main health-related priorities across participants is provided in Table 2.

During the six product-focused workshops, the "top 4" priorities were identified from the older adults to guide the co-creation of new ideas. These demonstrated the main concerns older adults have when considering their ongoing independence. These are summarised in Table 3.

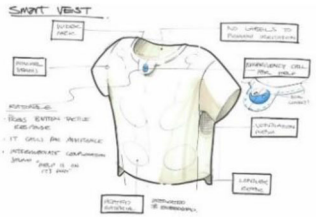
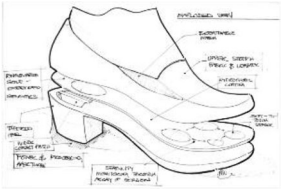
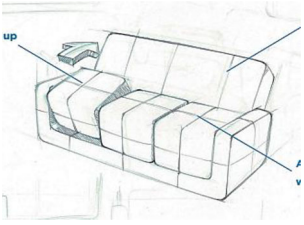
3.3. Smart assistive technology concepts

The workshops aimed to co-create AT concepts that would benefit from and employ SMs. The workshop activities enabled the prioritisation of health and independence needs (Table 3), and then the generation of ideas to address these needs. The older adults, and project partners from the MATUROLIFE multidisciplinary team, worked together to look at how functionality could be introduced through the use of SMs. Three examples of the concepts that were explored are shown in Table 4.

Table 3. Priorities for independence identified during the six product-focused workshops.

	France	Slovenia
Clothing	• Remind and / or help me to keep moving • Being able to control body temperature • Help check hydration levels and remind to eat • Help managing medication	• Alert others when I need help • Provide information on my vital signs • Being able to control body temperature. • Remind and / or help me to keep moving
	UK	Germany
Footwear	• Inform me about the risk of falling and change in my balance • Relieve or adapt to swelling of the feet • Help maintain a good temperature – and not get too hot or cold • Relieve aches and pains	• Relieve aches and pains • Relieve or adapt to swelling of the feet • Inform me about the risk of falling and change in my balance • Help me find my way around
	Poland	Turkey
Furniture	• I suffer from neck and back pain. • I need furniture that will support my changes in height and strength as I age • I sleep less well and have a poor sleep routine so often take naps during the day to help me recover • It would be good if people know when I need help	• I find it difficult to bend down and need things at the right height • I would like to be able to monitor my vital signs • I need furniture that will support my changes in height and strength as I age • It would be good if people knew when I needed help

Table 4. Examples of product concepts employing SMs.

Smart Products	Prioritised Functionalities	Workshop-based Concepts
Assistive Clothing	To help regulate temperature and encourage hydration	
Assistive Footwear	To improve balance and reduce falls	
Assistive Furniture	To enable improved sleep and mobility	

The older adult participants actively participated and debated the use of smart materials and technologies and how it could be used and adapted to be functional, discreet and unobtrusive.

> For deafness, he does not hear anything (not even the fire alarm); I have to write SMS. It could be very important to have a flashing or vibrating alarm. [FR, Workshop Participant #5]

> Either a voice or a beep warning to tell me that I need to drink, because my hydration level goes down. [UK, Workshop Participant #6]

> Garment could be linked to a wrist device or an interface printed onto the fabric for incontinence control, temperature regulation, and with the potential to be able to signal for help. [SI, Workshop Participant #3]

3.4. Design preferences and aesthetic requirements

The workshops identified design preferences and requirements for new products. There were many common requirements across the design of three product areas (clothing, footwear and furniture). The priority of good functionality was clear as "functional is more important than beautiful". Both male and female participants highlighted their preferences for comfort, "priority is comfort, not the look". However, it was also noted that there is an assumption that products for older adults do need to prioritise aesthetics and style, which was countered as fashion requirements by our participants.

> If I see something I like – like a floral t-shirt, I go and buy it. [UK Interview Participant #1]

> I am still looking for nice, colourful and modern things that I like. [FR Interview Participant #6]

> This is due to the way of dressing, because now people dress much more modern, even if they are older. [ES Workshop Participant #2]

> My shoes have to be fashionable and functional. [PL Interview Participant #5]

> Design is the thing that I consider when I purchase shoes. [UK Interview Participant #2]

Table 5. Design preferences and requirements generated for exemplar smart products.

Scenarios	Technologies to be considered	Design preferences
Clothing that controls body temperature and encourages hydration	• Sensor to record skin or close ambient temperature. • Heating circuits built into the garment. • No electronically activated cooling element and materials solution for cooling / ventilation. • Timed reminders to remind users to have a drink.	• Elegant and of good quality. • Styles should not be too tight or restrictive and suitable for multiple body shapes. • Plain not patterned fabrics in conservative colours such as grey, navy, black and brown. • Concerns of technology being placed near the heart.
Footwear that improves balance and reduces falls	• Network of pressure sensors in insole to map foot pressure / person's gait. • Sensors to detect ground or floor surface texture to alert the user of the fall and slip hazard. • Hand held alarm device (or device attaches to user jacket) that connects to shoes via Bluetooth to alert user of change in balance or ground surface.	• Classic in style. • Insoles might be interchangeable; changing the shape can change the function. • The insole should not be slippery. • Breathable in summer; waterproof, warm and cosy in the winter. • Stretchy or adjustable to adapt to the changes in foot shape. • Not too low at the front and a closed back.
Furniture that supports safety at home and enables improved sleep and mobility	• Ergonomic functions to support the sit / stand movement. • Pressure sensor to indicate breathing rate pattern. • Alerting a support network or emergency contact in the event of physical presence and reduced breathing.	• Strong preference for a modern and minimalist style. • Colours of warm greys, creams, blues and browns with natural materials. • Ease of installation and size of the furniture pieces, lightweight and easy to move. • Adjustable to different body shapes • Ergonomic factors to alter heights of seats and give neck supports.

> The smart clothes/shoes should be elegant. When you are elegant, you stay young. [FR, Workshop Participant #7]

It was made clear that if technology is embedded within a product to assist the user, it must be simple and straightforward to use. Some of the detailed preferences and requirements emerging from the collaborative working during the workshops are summarized in Table 5.

4. Discussion and Future Work

This paper outlines research undertaken to explore and improve the user acceptance of smart AT that is being developed as part of the

MATUROLIFE project. The participants involved in the interview and co-creation study were achieved through sampling across nine partner countries to represent an ageing population across Europe and to ensure adequate qualitative information was collected within a short time scale. The findings provide older adults' views on smart technology usage, their concerns for health and independence as they age, as well as their ideas for how these could be addressed through AT that embeds SMs, meanwhile to meet their fashion and aesthetic preference.

Based on the interviews and workshops, the critical factors for AT acceptance in the MATUROLIFE context are identified and suggested challenges to be addressed to increase/improve "ageing in place". According to our participants, it is important that digital literacy is taken into account and that, assistive or smart technologies are designed within the context of physical and social experiences to ensure they fully meet their needs and requirements. Product design from concepts through to the development and testing should be grounded in the every-day life activities of older adults to ensure that the functionalities and characteristics of the smart materials and technologies are deployed appropriately whilst aesthetically pleasing.

The workshops led to the definition of design scenarios with a user-led focus on sensing functionalities related to temperature, breathing, hydration, balance, mobility and alerting. Smart functionalities were co-created by the older adults and design team in order to tackle the top health-related issues prioritised by the older adults, such as "feel the cold more now", "easily get dehydrated", "fear of falling", "being unsteady on feet", and "poor sleep patterns". Our participants argued that AT products should be functional with a baseline level of aesthetics, technologically simple and straightforward, respectful toward their personalities and encourage social interaction and physical activity. The potential end users from a range of different European countries have defined design characteristics, materials and styles that could be customised in the clothing, footwear or furniture to share their desires and attitudes toward elderly fashion. There was some variation in style preferences as might be expected, and this will be considered as a range of style options that are developed in consultation with a stakeholder and user panel.

SMs were introduced to provide our participants an understanding of how high tech AT might be developed to respond to users' needs and desires thus acting as a hidden caregiver (Micocci 2017; Spinelli, Micocci, and Ajovalasit 2016), whilst being comfortable and aesthetically pleasing. It is argued that the participants do not need to have in-depth technical knowledge of SMs, but they do need to understand what functionalities these smart materials will bring to them and the potential risks and data issues that might emerge, as well the potential aesthetic limitations. These will be ensured and further evaluated through iterative prototyping and testing. Our ongoing work is focused

on realising the smart AT ideas shaped by experiences and opinions of older adult participants in interview and co-creation study outlined here. The process of development is iterative which aims to involve older adults and stakeholders in the continued product development and evaluation.

Borg, Larsson, and Östergren (2011) argue it is necessary to look beyond the technology and the physical features of the user. Other important factors including accessibility to technologies, needs to everyday life, personal preferences and expectations have been brought to the forefront (Quinn 2010; Borg, Larsson, and Östergren 2011). In this study, we especially argued that reducing age-related stigma in the design of effective AT is crucial and could influence fashion practice in relation to elderly users. The use of interviews and workshops as a way of engaging older adults as our primary end-user has enabled us to understand and map these preferences and expectations, and then begin to co-develop solutions. The practical importance of the MATUROLIFE project lies in the human-centred design methodology that bridges the understanding between the designers, engineers, scientists and the older adults. By embodying a participatory approach in designing smart AT products, key requirements were captured to help improving AT acceptance and potentially break down the barriers of future AT product adoption.

The development of functional and smart textiles is accelerating due to a gradual reduction of component costs, rising consumer interest, and improving technologies (Palamutcu and Goren 2015). This provides an opportunity for wearable, fashionable and discrete AT. Armstrong, Najafi, and Shahinpoor (2017) propose that smart multifunctional materials have potential applications in addressing age-related issues. We are interested in the acceptability of these developments and understanding further the willingness of older adults to buy-in to and use SMs–based products. By involving older adults in the specification of product functionality and aesthetics, as well explaining the potential of SMs, we hope to open up the possibilities for how SMs are used and how quickly the benefits can be realised for older adults. It is also an implication for research practice to explore the potential of SMs in fashion for older adults recognising the opportunity for innovation.

Acknowledgements

The authors wish to sincerely thank the participating older adults who gave their time for the co-creation activity. Any dissemination reflects the authors' view only and the European Commission is not responsible for any use that may be made of the information it contains. The views and opinions expressed in this paper are those of the authors and are not intended to represent the position or opinions of the MATUROLIFE consortium or any of the individual partner organisations.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

MATUROLIFE (Metallisation of Textiles to make Urban Living for Older People more Independent and Fashionable) project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 760789.

ORCID

Danying Yang http://orcid.org/0000-0002-3824-6650
Louise Moody http://orcid.org/0000-0003-2326-4124

References

Armstrong, D. G., B. Najafi, and M. Shahinpoor. 2017. "Potential Applications of Smart Multifunctional Wearable Materials to Gerontology." *Gerontology* 63 (3): 287–298. doi:10.1159/000455011.

Azar, G. T. P., D. Fox, Y. Fedutik, L. Krishnan, and A. Cobley. 2020. "Functionalised Copper Nanoparticle Catalysts for Electroless Copper Plating on Textiles." *Surface and Coatings Technology* 396: doi:10.1016/j.surfcoat.2020125971.

Bate, P., and G. Robert. 2006. "Experience-Based Design: From Redesigning the System around the Patient to co-Designing Services with the Patient." *Quality & Safety in Health Care* 15 (5): 307–310. doi:10.1136/qshc.2005.016527.

Bazeley, P., and K. Jackson. 2013. *Qualitative Data Analysis with NVivo*. London: SAGE Publications Ltd.

Bernard, G., and P. Andritsos. 2017. "A Process Mining Based Model for Customer Journey Mapping." In *Forum and Doctoral Consortium Papers Presented at the 29th International Conference on Advanced Information Systems Engineering (CAiSE 2017)*, Essen, Germany.

Bloom, D. E., S. Chatterji, P. Kowal, P. Lloyd-Sherlock, M. McKee, B. Rechel, L. Rosenberg, and J. P. Smith. 2015. "Macroeconomic Implications of Population Ageing and Selected Policy Responses." *The Lancet* 385 (9968): 649–657. doi:10.1016/S0140-6736(14)61464-1.

Borg, J., S. Larsson, and P. O. Östergren. 2011. "The Right to Assistive Technology: For Whom, for What, and by Whom?" *Disability & Society* 26 (2): 151–167. doi:10.1080/09687599.2011.543862.

Boucher, P. 2018. *Assistive Technologies for People with Disabilities: In-Depth Analysis*. Brussels: STOA – Science and Technology Options Assessment.

Boyatzis, R. E. 1998. *Transforming Qualitative Information: Thematic Analysis and Code Development*. Thousand Oaks, CA: SAGE Publications.

Cameron, C. A., and A. K. Hunt. 2018. "'A Day in the Life': A Visual, Multimedia Approach to Research." In *SAGE Research Methods Cases*. London: SAGE Publications Ltd.

Couvreur, L. D., W. Dejonghe, J. Detand, and R. Goossens. 2013. "The Role of Subjective Well-Being in Co-Designing Open-Design Assistive Devices." *International Journal of Design* 7 (3): 57–70.

Davies, R., R. Fukuda, H-m Hua, S. Martin, M. Mulvenna, and S. Merkel. 2016. "Assistive Technology for Older People." In *Gerontechnology: Research, Practice, and Principles in the Field of Technology and Aging*, edited by Sunkyo Kwon, 252. New York, NY: Springer Publishing Company.

Demers, L., W. B. Mortenson, M. J. Fuhrer, J. W. Jutai, M. Plante, J. Mah, and F. DeRuyter. 2016. "Effect of a Tailored Assistive Technology Intervention on Older Adults and Their Family Caregiver: A Pragmatic Study Protocol." *Geriatrics* 16 (103): 2–11. doi:10.1186/s12877-016-0269-3.

Donetto, S., P. Pierri, V. Tsianakas, and G. Robert. 2015. "Experience-Based Co-Design and Healthcare Improvement: Realizing Participatory Design in the Public Sector." *The Design Journal* 18 (2): 227–248. doi:10.2752/175630615X14212498964312.

Elg, M. H., J. Engström, L. Witell, and B. B. Poksinska. 2012. "Co-Creation and Learning in Health-Care Service Development." *Journal of Service Management* 23 (3): 328–343. doi:10.1108/09564231211248435.

Fisk, A., W. A. Rogers, S. J. Czaja, N. Charness, and J. Sharit. 2009. *Designing for Older Adults: Principles and Creative Human Factors*. Florida: CRC Press.

Frid, L., A. García, I. Laskibar, A. Etxaniz, and M. F. Gonzalez. 2013. "What Technology Can and Cannot Offer an Ageing Population: Current Situation and Future Approach." In *A Multimodal End-2-End Approach to Accessible Computing*, edited by Pradipta Biswas, Carlos Duarte, Patrick Langdon, Luis Almeida, and Christoph Jung, 3–22. London: Springer.

Frow, P., J. R. McColl-Kennedy, and A. Payne. 2016. "Co-Creation Practices: Their Role in Shaping a Health Care Ecosystem." *Industrial Marketing Management* 56: 24–39. doi:10.1016/j.indmarman.2016.03.007.

Galvagno, M., and D. Dalli. 2014. "Theory of Value co-Creation: A Systematic Literature Review." *Managing Service Quality* 24 (6): 643–683. doi:10.1108/MSQ-09-2013-0187.

Gaßner, K., and M. Conrad. 2010. *ICT Enabled Independent Living for the Elderly: A Status-Quo Analysis on Products and the Research Landscape in the Field of Ambient Assisted Living (AAL) in EU-27*. Berlin, Germany: Institute for Innovation and Technology of Germany.

Gokarneshan, N., and G. N. Srivatsav. 2018. "Some Significant Trends in Conductive Textiles." *Trends in Textile and Fashion Designing* 2 (3): 179–186. doi:10.32474/LTTFD.2018.02.000136.

Gonçalves, C., A. F. d Silva, J. Gomes, and R. Simoes. 2018. "Wearable E-Textile Technologies: A Review on Sensors, Actuators and Control Elements." *Inventions* 3 (1): 14. doi:10.3390/inventions3010014.

Holliday, N., D. Awang, and G. E. Ward. 2018. "Co-Creating Well-Being Experiences with Assistive Living Technologies." In *Pathways to Well-Being in Design: Examples from the Arts, Humanities and the Built Environment*, edited by Richard Coles, Sandra Costa, and Sharon Watson, 34–53. London: Routledge.

Holliday, N., P. Magee, and A. Walker-Clarke. 2015. "Reflections on Creative Methodologies for Health Technology Research, and the Iterative Process between Research and Design." In *Design4Health: 2015 European Conference*, Sheffield, UK.

Hwang, D., and W. Park. 2018. "Design Heuristics Set for X: A Design Aid for Assistive Product Concept Generation." *Design Studies* 58: 89–126. doi:10.1016/j.destud.2018.04.003.

Iecovich, E. 2014. "Aging in Place: From Theory to Practice." *Anthropological Notebooks* 20 (1): 21–33.

Ind, N., and N. Coates. 2013. "The Meanings of co-Creation." *European Business Review* 25 (1): 86–95. doi:10.1108/09555341311287754.

Jin, H., Q. Jin, and J. Jian. 2018. "Smart Materials for Wearable Healthcare Devices." In *Wearable Technologies*, edited by Jesús Hamilton Ortiz, 109–138. London: IntechOpen.

Kim, K., and K-p Lee. 2016. "Collaborative Product Design Processes of Industrial Design and Engineering Design in Consumer Product Companies." *Design Studies* 46: 226–260. doi:10.1016/j.destud.2016.06.003.

Koncar, V. 2019. "Smart Textiles for Monitoring and Measurement Applications." In *Smart Textiles for in Situ Monitoring of Composites*, edited by Vladan Koncar, 1–151. Cambridge, UK: Woodhead Publishing.

Lancioni, G. E., and N. N. Singh. 2014. *Assistive Technologies for People with Diverse Abilities*. Edited by Johnny L. Matson, Autism and Child Psychopathology Series. New York: Springer.

Lee, J. H., J. Ahn, and J. Kim. 2018. "Theoretical Competence Model of Fashion Designers in Co-Designed Fashion Systems." *Fashion Practice* 10 (3): 381–404. doi:10.1080/17569370.2018.1507150.

Lee, C., and J. F. Coughlin. 2015. "PERSPECTIVE: Older Adults' Adoption of Technology: An Integrated Approach to Identifying Determinants and Barriers." *Journal of Product Innovation Management* 32 (5): 747–759. doi:10.1111/jpim.12176.

Malterud, K., V. D. Siersma, and A. D. Guassora. 2016. "Sample Size in Qualitative Interview Studies: Guided by Information Power." *Qualitative Health Research* 26 (13): 1753–1760. doi:10.1177/1049732315617444.

Marasinghe, K. M. 2016. "Assistive Technologies in Reducing Caregiver Burden among Informal Caregivers of Older Adults: A Systematic Review." *Disability and Rehabilitation: Assistive Technology* 11 (5): 353–360. doi:10.3109/17483107.2015.1087061.

Martin, B., and B. Hanington. 2012. *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. Beverly, MA: Rockport Publishers.

Martins, A. C., J. Pinheiro, B. Farias, and J. Jutai. 2016. "Psychosocial Impact of Assistive Technologies for Mobility and Their Implications for Active Ageing." *Technologies* 4 (3): 28. doi:10.3390/technologies4030028.

Micocci, M., and G. Spinelli. 2018. "Metaphors and Analogies through Smart Materials to Mitigate Age-Related Differences in the Understanding of Technology." *Journal of Design Research* 16 (3–4): 282–313. doi:10.1504/JDR.2018.099536.

Micocci, M. 2017. "Smart Materials and Metaphors to Enhance Technology Adoption among Older Adults." Doctoral dissertation, Brunel University London.

Moody, L., and A. Cobley. 2020. "MATUROLIFE: Using Advanced Material Science to Develop the Future of Assistive Technology." In *Design of Assistive Technology for Ageing Populations*, edited by Andree Woodcock, Louise Moody, Deana McDonagh, Ajita Jain, and Lakhmi Jain, 189–202. Switzerland: Springer Nature.

NIHR. 2018. *Help at Home: Use of Assistive Technology for Older People*. UK: The National Institute for Health Research.

Nowell, L. S., J. M. Norris, D. E. White, and N. J. Moules. 2017. "Thematic Analysis: Striving to Meet the Trustworthiness Criteria." *International Journal of Qualitative Methods* 16 (1): 160940691773384. 13. doi:10.1177/1609406917733847.

NSTC. 2019. *Emerging Technologies to Support an Aging Population*. Washington DC: National Science and Technology Council (NSTC) and Office of Science and Technology Policy (OSTP).

Palamutcu, S., and I. Goren. 2015. "Functional Textile Preferences of Elderly People." *Mediterranean Journal of Social Sciences* 6 (2): 279–285. doi:10.5901/mjss.2015.v6n2s5p279.

Partridge, L., J. Deelen, and P. E. Slagboom. 2018. "Facing up to the Global Challenges of Ageing." *Nature* 561 (7721): 45–56. doi:10.1038/s41586-018-0457-8.

Peek, Sebastiaan T. M., Eveline J. M. Wouters, Joost van Hoof, Katrien G. Luijkx, Hennie R. Boeije, and Hubertus J. M. Vrijhoef. 2014. "Factors Influencing Acceptance of Technology for Aging Inplace: A Systematic Review." *International Journal of Medical Informatics* 83 (4): 235–248. doi:10.1016/j.ijmedinf.2014.01.004.

Pilotto, A., R. Boi, and J. Petermans. 2018. "Technology in Geriatrics." *Age and Ageing* 47 (6): 771–774. doi:10.1093/ageing/afy026.

Profita, H. P. 2016. "Designing Wearable Computing Technology for Acceptability and Accessibility." *ACM SIGACCESS Accessibility and Computing* 114 (114): 44–48. doi:10.1145/2904092.2904101.

Quinn, K. 2010. "Methodological Considerations in Surveys of Older Adults: Technology Matters." *International Journal of Emerging Technologies and Society* 8 (2): 114–133. doi:10.13140/2.1.3897.9209.

Ritchie, J., J. Lewis, C. M. Nicholls, and R. Ormston. 2014. *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. London: SAGE Publications.

Sanders, E. B.-N., and P. J. Stappers. 2008. "Co-Creation and the New Landscapes of Design." *International Journal of CoCreation in Design and the Arts* 4 (1): 5–18. doi:10.1080/15710880701875068.

Schreier, M. 2012. *Qualitative Content Analysis in Practice*. London: SAGE Publications.

Spinelli, G., M. Micocci, and M. Ajovalasit. 2016. "Behavioral Strategies of Older Adults in the Adoption of New Technology-Based Products: The Effects of Ageing and the Promising Application of Smart Materials for the Design of Future Products." In *Design for Healthcare*, edited by Emmanuel Tsekleves and Rachel Cooper. London: Gower & Ashgate Publishing.

Stoppa, M., and A. Chiolerio. 2014. "Wearable Electronics and Smart Textiles: A Critical Review." *Sensors* 14 (7): 11957–11992. doi:10.3390/s140711957.

Tang, S. L. P., and G. K. Stylios. 2006. "An Overview of Smart Technologies for Clothing Design and Engineering." *International Journal of Clothing Science and Technology* 18 (2): 108–128. doi:10.1108/09556220610645766.

Tao, X. 2001. *Smart Fibres, Fabrics and Clothing*. Cambridge: CRC Woodhead Publishing Ltd.

Townsend, K., A. Sadkowska, and J. Sissons. 2017. "Emotional Fit: Developing a New Fashion Methodology with Older Women." *Clothing Cultures* 4 (3): 235–251. doi:10.1386/cc.4.3.235_1.

Twigg, J. 2013. *Fashion and Age: Dress, the Body and Later Life*. London: Bloomsbury.

WHO. 2018. *Assistive Technology*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/assistive-technology

Wiles, J. L., A. Leibing, N. Guberman, J. Reeve, and R. E. S. Allen. 2012. "The Meaning of 'Aging in Place' to Older People." *The Gerontologist* 52 (3): 357–366. doi:10.1093/geront/gnr098.

Yang, D. 2012. "The Design of Mood Changing Clothing Based on Fibre Optics and Photovoltaic Technologies." Doctoral dissertation. Heriot Watt University.

Yang, D., and L. Moody. 2020. "Challenging Stigma by Embodying Smart Functionalities and Fashion in Assistive Clothing co-Designed with Older Adults." In *6th International Conference on Design4Health*, Amsterdam, NL, July 1.

Yusif, S., J. Soar, and A. Hafeez-Baig. 2016. "Older People, Assistive Technologies, and the Barriers to Adoption: A Systematic Review." *International Journal of Medical Informatics* 94: 112–116. doi:10.1016/j.ijmedinf.2016.07.004.